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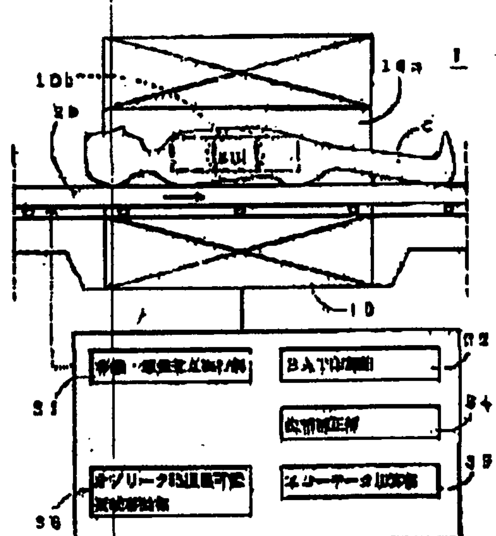
(54) IMAGE PICKUP DEVICE USING MRI DEVICE

(57)Abstract:



PURPOSE: To obtain an image of an image pickup object range being larger than an image pickup available area of the MRI device by one time reconstituting operation.
CONSTITUTION: A movement/image pickup alternately executing part 31 divides an image pickup object range being larger than an image pickup available area 10b of an MRI device 10 into plural partial areas R (i) being smaller than or equal to the image pickup available area 10b. Subsequently, the partial areas R(i) are inserted into the image pickup available area 10b in order and stopped, and echo data are collected by both the same gradient as that for picking up the whole of the image pickup object range and the sequence of the number of sampling. A phase correcting part 34 performs a phase correction to each echo data. Subsequently, an echo data adding part 35 adds each piece of echo data after the phase correction. By executing a reconstituting operation to the added echo data, an image of the whole of the image pickup object range is obtained.

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(54) Title of the Invention: Imaging apparatus using MRI device

(57) Abstract

Purpose: To obtain an image over an imaging range larger than the imageable region of an MRI device, by means of a single reconstruction operation.

Constitution: A movement/imaging alternating execution unit 31 divides an imaging range larger than the imageable region 10b of the MRI device 10 into a plurality of subregions R(i), smaller than or equal to the imageable region 10b. The subregions R(i) are placed, in order, in the imageable region 10b and held stationary, and echo data K(i) is collected using a sequence with the same gradient and number of samples as when imaging the entire imaging range. The phase correction unit 34 performs phase correction of each set of echo data K(i). Then, the echo data addition unit 35 adds each set of phase-corrected echo data. By performing reconstruction on the echo data after addition, an image of the entire imaging range can be obtained.

Claims

Claim 1: An imaging apparatus, comprising an MRI device, and a movement device which moves the object for imaging, which is to pass through the bore of the MRI device, relative to the MRI device; and further comprising

movement/imaging alternating execution means, which, when the length in the direction of relative movement of the imaging range is longer than the length in the direction of relative movement of the imageable region of the MRI device, divides said imaging range into a plurality of subregions, such that the length in the direction of relative movement of each subregion is smaller than or equal to the length in the direction of relative movement of said imageable region, moves the object for imaging so as to place one of said subregions in said imageable region, stops movement, collects echo data using a sequence with the same gradient and number of samples as when imaging the entirety of said imaging range, and repeats this operation for each subregion;

phase correction means, which performs phase correction on the obtained plurality of echo data sets, according to the position of each subregion in said imaging range; and,

echo data addition means, which adds each set of phase-corrected echo data;

and wherein an image of the entirety of said imaging range is reconstructed from said added echo data.

Claim 2: An imaging apparatus, comprising an MRI device, and a movement device which moves the object for imaging, which is to pass through the bore of the MRI device, relative to the MRI device; and further comprising

movement/imaging simultaneous execution means, which, when the length in the direction of relative movement of the imaging range is longer than the length in the direction of relative movement of the imageable region of the MRI device, divides said imaging range into a plurality of subregions, such that the length in the direction of relative movement of each subregion is smaller than or equal to the length in the direction of relative movement of said imageable region, and, while moving the object for imaging

at a speed Gv smaller than or equal to the quotient (Mw-Gw)/Mt, which is the length in the direction of relative movement of said imageable region Mw, minus the length in the direction of relative movement of one subregion Gw, divided by the time to collect one image's worth of data over the entirety of said imaging range Mt, collects echo data using a sequence with the same gradient and number of samples as when imaging the entirety of said imaging range, while one subregion is within said imageable region, and repeats this operation for each subregion;

phase correction means, which performs phase correction on the obtained plurality of echo data sets, according to the position of each subregion in said imaging range; and,

echo data addition means, which adds each set of phase-corrected echo data;

and wherein an image of the entirety of said imaging range is reconstructed from said added echo data.

Detailed Description of the Invention

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Industrial Field of the Invention

This invention relates to an imaging apparatus using an MRI device, and more specifically, to an imaging apparatus which is capable of imaging with the MRI device even when the region for imaging is larger than the imageable region of the MRI device.

0002

Prior Art

Imaging apparatus comprising an MRI device, and a movement device to move the object for imaging so as to pass through the bore of the MRI device, is disclosed in, for example, Japanese Patent Laid-open No. 63-272335. In this conventional imaging apparatus, when the imaging plane is parallel to the direction of motion, first the movement of the object for imaging G is stopped, imaging is performed, and a first image, of length T in the movement direction, is obtained. Then, after movement by a distance T, movement is again stopped, imaging is performed, and a second image, of length T in the movement direction, is obtained. This is repeated M times, and the M images obtained, from the first to the Mth, are joined together to obtain an image of length MT. Fig. 16 is a schematic diagram of the configuration of the above conventional imaging apparatus. G is the object for imaging (the patient); 60 is a cradle which moves the object for imaging G; 50 is the MRI device; 50a is the bore; and 50b is the imageable region. 51 is a movement/imaging alternating execution unit, which executes in alternation movement of the object for imaging G by means of the cradle 60 and imaging by means of the MRI device, and is part of the MRI device 50. 52 is the image joining unit, and is part of the MRI device 50. The movement/imaging alternating execution unit 51 places the subregions R(1), R(2), R(3) in order in the imageable region 50b, stops the [movement], and performs imaging to obtain the images Z1, Z2, Z3 shown in Fig. 17. The image joining unit 52 joins the images Z1, Z2, Z3, to create a single image ZL of length L in the movement direction, larger than the imageable region 50b.

0003

Problem to be Solved by the Invention

In the above conventional imaging apparatus, because the M images, from the first to the Mth, must be obtained separately, M reconstruction operations are necessary, and so there is the problem that long processing time is required. In addition, in order to avoid blurring and spurious images, called motion artifacts, the movement device is stopped each time imaging is performed by the MRI device; but frequent stopping of movement causes the problem of reduced efficiency. Hence a first object of this invention is to provide an imaging apparatus which can obtain an image which joins together M images through a single reconstruction operation. A second object of this invention, in addition to the above first object, is to provide an imaging apparatus capable of imaging using an MRI device without stopping the movement of the object for imaging.

0004

Means to Solve the Problem

In a first aspect, this invention provides an imaging apparatus comprising an MRI device, and a movement device which moves the object for imaging, which is to pass through the bore of the MRI device, relative to the MRI device; and further comprising (a) movement/imaging alternating execution means, which, when the length in the direction of relative movement of the imaging range is longer than the length in the direction of relative movement of the imageable region of the MRI device, divides the imaging range into a plurality of subregions, such that the length in the direction of relative movement of each subregion is smaller than or equal to the length in the direction of relative movement of the imageable region, moves the object for imaging so as to place one of the subregions in the imageable region, stops movement, collects echo data using a sequence with the same gradient and number of samples as when imaging the entirety of the imaging range, and repeats this operation for each subregion; (b) phase correction means, which performs phase correction on the obtained plurality of echo data sets, according to the position of each subregion in the imaging range; and, (c) echo data addition means, which adds each set of phase-corrected echo data.

0005

In a second aspect, this invention provides an imaging apparatus comprising an MRI device, and a movement device which moves the object for imaging, which is to pass through the bore of the MRI device, relative to the MRI device and further comprising (a) movement/imaging simultaneous execution means, which, when the length in the direction of relative movement of the imaging range is longer than the length in the direction of relative movement of the imageable region of the MRI device, divides said imaging range into a plurality of subregions, such that the length in the direction of relative movement of each subregion is smaller than or equal to the length in the direction of relative movement of said imageable region, and, while moving the object for imaging at a speed Gv smaller than or equal to the quotient (Mw-Gw)/Mt, which is the length in the direction of relative movement of said imageable region Mw, minus the length in the direction of relative movement of one subregion Gw, divided by the time to collect one image's worth of data over the entirety of said imaging range Mt, collects echo data using a sequence with the same gradient and number of samples as when imaging the entirety of said imaging range, while one subregion is within said imageable region, and repeats

this operation for each subregion; (b) phase correction means, which performs phase correction on the obtained plurality of echo data sets, according to the position of each subregion in said imaging range; and, (c) echo data addition means, which adds each set of phase-corrected echo data.

0006

Action

In the imaging apparatus of the above first aspect, when the length in the direction of relative movement of the imaging range is greater than the length in the direction of relative movement of the imageable region of the MRI device, the movement/imaging alternating execution means divides the imaging range into a plurality of subregions. However, the length in the direction of relative movement of each subregion is smaller than or equal to the length in the direction of relative movement of the above imageable region. Then the object for imaging is moved, placing one of the above subregions in the above imageable region, movement is stopped, and echo data is collected using a sequence with the same gradient and number of samples as when imaging the entirety of the above imaging range. This is repeated for each subregion, to obtain a plurality of echo data sets. However, despite the fact that the positions of each subregion in the imaging range are different, this plurality of echo data sets has the same phase. Then, the phase correction means performs phase correction according to the position of each subregion with respect to the above imaging range, so as to correct the relation between the phase and the position in the imaging range. Next, the echo data addition means adds the phase-corrected echo data sets. Through the above, echo data is obtained equivalent to the result of imaging the entirety of the imaging range, so that by performing a reconstruction operation on this [echo data], an image is obtained for the entirety of the imaging range. Thus an image in which a plurality of images are joined together can be obtained from a single reconstruction operation.

0007

In the imaging apparatus of the above second aspect, when the length in the direction of relative movement of the imaging range is greater than the length in the direction of relative movement of the imageable region of the MRI device, the movement/imaging simultaneous execution means divides the above imaging range into a plurality of subregions. Here the length in the direction of relative movement of each subregion is made smaller than or equal to the length in the direction of relative movement of the above imageable region. The object for imaging is then moved, to place one of the above subregions in the above imageable region, and while moving the object for imaging, echo data is collected using a sequence with the same gradient and number of samples as when imaging the entirety of the above imaging range. However, movement is performed at a speed Gv which is less than or equal to the quotient (Mw-Gw)Mt of the length Mw of the MRI device imageable area in the direction of movement minus the length Gw of one subregion in the direction of movement, divided by the time Mt required to collect one image's worth of data for the entire imaging range. This is repeated for each subregion, and a plurality of echo data sets is obtained. Despite the fact that the positions of each subregion in the imaging range are different, the phases of this plurality of echo data sets are the same. Hence the phase correction means performs phase correction according to

the position in the above imaging range of each subregion, to correct the relation between the phase and the position in the imaging range. Then, the echo data addition means adds the phase-corrected echo data. By this means, echo data is obtained which is equivalent to that obtained by imaging the entire imaging range, so that by performing a single reconstruction operation, an image of the entirety of the imaging range is obtained. If the speed is the speed Gv of the above-described condition, data for one image's worth of a subregion can be collected during the period that the object for imaging is in the imageable region. If super-fast imaging is performed using the MRI device, with for example Mt=Several hundreds ms or less, the movement of the object for imaging is small even if the speed Gv is a practical speed, so that there is little blurring or occurrence of spurious images, called motion artifacts, and the image is not greatly degraded. Hence imaging can be performed while moving the object for imaging continuously, so that efficiency can be increased. And, an image in which are joined a plurality of images can be obtained through a single reconstruction operation.

0008

Embodiments

Below, this invention explained in greater detail, based on the embodiments shown in the drawings. This invention is not limited by these [embodiments]. Fig. 1 is a schematic diagram of the imaging apparatus using an MRI device of one embodiment of this invention. G is the object for imaging (the patient), 20 is a cradle which moves the object for imaging G, 10 is the MRI device, 10a is the bore, and 10b is the imageable region. The MRI device 10 comprises a movement/imaging alternating execution unit 31, an SAT application unit 32, a phase correction unit 34, an echo data addition unit 35, and an oblique imageable region movement unit 36.

0009

Fig. 2 is a flowchart of the operation of data collection processing executed by the movement/imaging alternating execution unit 31 and the SAT application unit 32. Processing in steps where the number 31 appears is performed by the movement/imaging alternating execution unit 31; processing in steps where the number 32 appears is performed by the SAT application unit 32. In step 31A, the processing counter is set to i=1. In step 31B, the cradle 20 is controlled to place the subregion R(i) of the object for imaging G in the imageable region 10b. Initially, i=1, and so the subregion R(1) is placed in the imageable region 10b. Thereafter, subregions are placed in the imageable region 10b in order, R(2), ..., R(M). Here the subregion R(i) is, as shown in Fig. 3, a subregion resulting from division of the imaging range into M [subregions] when the length L in the movement direction of the imaging range is greater than the length in the movement direction of the imageable region 10b. The length in the movement direction of each subregion R(i) is equal to or less than the length in the movement direction of the imageable region. It is not necessary that the length in the movement direction of each subregion R(i) be equal; but if equal, the length is equal to L/M.

0010

In step 31C, a pulse sequence is created with the same gradient and number of samples as when imaging N pixels of an imaging range of length L. That is, if the movement

direction is the frequency axis direction, the readout gradient Gf and sampling interval ΔTf satisfy the relation $\gamma Gf\Delta Tf=2\pi/LN$. On the other hand, when the movement direction is in the phase axis direction, a square wave (or waveform with equivalent area) having warp gradient Gp and time width ΔTp satisfying the relation

$$\gamma Gp\Delta Tp = 2\pi n/LN \quad (n=-(N/2)+1, \cdots, N/2)$$

is employed as the phase encoding.

0011

In step 32D, prior to the above pulse sequence, a spatial saturation pulse (spatial SAT pulse) is applied as necessary, to suppress the occurrence of MR signals from regions other than the subregion R(i).

0012

In step 31E, data K(i) for one image is collected. In steps 31F, 31G, the above steps 31B to 31E are repeated until i=M. Through the above process, the echo data K(1) to K(M) shown in Fig. 4 is collected.

0013

Fig. 5 is a flowchart showing the operation of the data correction and addition processing which is executed by the phase correction unit 34 and echo data addition unit 35. Processing in steps where the number 34 appears is performed by the phase correction unit 34; processing in steps where the number 35 appears is performed by the echo data addition unit 35. In step 34A, the processing counter is i=1. In step 34B, the data K(i)(f,p) is multiplied by $\exp\{j\pi a(1-i/M)\}$ (where, if the movement direction is the frequency axis direction, a is f, and if the phase axis direction, a is p, and is an integer from (-N/2)+1 to N/2), to obtain the corrected data K(i)(f,p). In steps 34C, 34D, the above step 34B is repeated until i=M, to add the corrected data K(1) to K(M). By this means, the echo data $K\Sigma$ shown in Fig. 4 is obtained.

0014

Next, the principle of the above data correction and addition processing is explained. if the position in the movement direction is x, and the signal source is g(x), then the echo data KL(a) for the entire imaging range can be expressed as shown in eq. (1).

0015

Equation (1)

$$KL(a) = \int_{-\frac{L}{2}}^{\frac{L}{2}} g(x)\, e^{-j\frac{2\pi}{L}ax} dx$$

0016

Consider a function g(i)(x) which takes on a value equal to g(x) within one subregion only, and is "0" in other subregions; then the echo data KL(a) can be expressed as in eq. (2).

0017

Equation (2)

$$
\begin{aligned}
KL(a) &= \int_{-\frac{L}{2}}^{\frac{L}{2}} \sum_{i=1}^{M} g(i)(x)\, e^{-j\frac{2\pi}{L}ax}\, dx \\
&= \sum_{i=1}^{M} \int_{-\frac{L}{2}}^{\frac{L}{2}} g(i)(x)\, e^{-j\frac{2\pi}{L}ax}\, dx \\
&= \sum_{i=1}^{M} \int_{-\frac{L}{2}+\frac{L}{2M}(i-1)}^{-\frac{L}{2}+\frac{L}{2M}i} g(i)(x)\, e^{-j\frac{2\pi}{L}ax}\, dx \\
&= \sum_{i=1}^{M} \int_{-\frac{L}{2M}}^{\frac{L}{2M}} g(i)\left(x-\frac{L}{2}+\frac{L}{2M}i\right) e^{-j\frac{2\pi}{L}ax}\, dx\; e^{-j\frac{2\pi}{L}a\left(-\frac{L}{2}+\frac{L}{2M}i\right)} \\
&= \sum_{i=1}^{M} e^{j\pi a\left(1-\frac{i}{M}\right)} \int_{-\frac{L}{2M}}^{\frac{L}{2M}} g(i)\left(x-\frac{L}{2}+\frac{L}{2M}i\right) e^{-j\frac{2\pi}{L}ax}\, dx \\
&= \sum_{i=1}^{M} e^{j\pi a\left(1-\frac{i}{M}\right)} K(i)(a)
\end{aligned}
$$

0018

Here K(i)(a) is the echo data collected on excitation of only the subregion R(i) after placing the subregion R(i) in the center of the magnetic field, and is the data collected in the data collection of Fig. 2. Hence the echo data KΣ obtained in the above data correction and addition processing is equivalent to KL(a) in eq. (2), and is the echo data over the entirety of the imaging range. Hence by performing a reconstruction operation, as shown in Fig. 4, on the echo data KΣ obtained in the above data correction and addition processing, an image ZL of the entirety of the imaging range can be obtained.

0019

Fig. 6 is a flowchart of the operation of the oblique imageable region movement unit 36. In step 36A, movement is performed to align the position of the imageable region 10b with the subregion R(i). That is, during oblique imaging, as shown in Fig. 7, movement is also performed in the direction orthogonal to the direction of movement of the subregion R(i). The position of the imageable region 10b is also moved in accordance with this [movement]. More specifically, movement of the imageable region 10b can be realized by, for example, shifting the RF frequency.

0020

As is clear from the above explanation, by means of the imaging apparatus 1 of the above embodiment, even when the imaging range is larger than the imageable region of the MRI device, imaging by the MRI device is possible; moreover, images of the entire imaging range (sagittal image, coronal image, three-dimensional image, oblique image) can be obtained by a single reconstruction operation. And because echo data is added, the S/N ratio is also improved. Hence measurements of, for example, distances in the longitudinal direction, overall volumes, and surface areas can be performed accurately.

Moreover, the region of high uniformity of the magnetic field of the MRI device can be made thin in the cradle direction, independently of the length of the imaging range, so that magnets can be made thin, the installation area can be reduced, and the feeling of oppression imposed on the patient can be alleviated.

0021

It is general practice to apply a spatial saturation pulse using the SAT application unit 32, and rapidly extract one subregion; but in order to smooth the seams [between] the subregions, the boundary vicinities of subregions may be gently dropped. In this case, it is necessary to also insert part of the neighboring subregions into the imageable region. As the method for gently dropping the boundary vicinities of subregions, modifications may be made to the spatial saturation pulse waveform, to the RF coil sensitivity distribution, or to the RF receiver filter characteristics, or similar.

0022

Also, this invention, with superior S/N ratio, and the conventional method (of joining the images of each subregion), with its excellent spatial resolution, may be used selectively for each subregion, to achieve a balance between S/N ratio and spatial resolution.

0023

Fig. 8 is a schematic diagram of the imaging apparatus 2 using an MRI device of another embodiment of this invention. G is the object for imaging (the patient); 20 is a cradle; 40 is the MRI device; 40a is the bore; and 40b is the imageable region. The MRI device 40 comprises a movement/imaging alternating execution unit 31; a SAT application unit 32; a phase correction unit 34; an echo data addition unit 35; and an oblique imageable region movement unit 36. These are the same as the component elements explained in the imaging apparatus 1 of the previous embodiment, and an explanation is omitted. The MRI device 40 further comprises a movement/imaging simultaneous execution unit 11; a correction requirement judgment unit 12; a continuous-movement SAT application unit 14; a continuous-movement phase correction unit 15; and an oblique/three-dimensional integrated control unit 16.

0024

Of the combination of the movement/imaging alternating execution unit 31 and SAT application unit 32, and the combination of the movement/imaging simultaneous execution unit 11 and the continuous movement SAT application unit 12, only the combination selected by the operator is started. When the combination of the movement/imaging alternating execution unit 31 and the SAT application unit 32 is started, the operation is the same as for the imaging apparatus 1 of the previous embodiment, and so an explanation is omitted. In this case, the movement/imaging simultaneous execution unit 11, correction requirement judgment unit 12, continuous movement SAT application unit 14, continuous movement phase correction unit 15, and oblique/three-dimensional integrated control unit 16 do not operate at all. When the combination of the movement/imaging simultaneous execution unit 11 and the continuous movement SAT application unit 12 is started, the correction requirement judgment unit 12, continuous movement SAT application unit 14, continuous movement phase correction unit 15, and oblique/three-dimensional integrated control unit 16 are

started, and while moving the cradle 20 continuously, echo data K(i) is collected for each subregion R(i). Operation after collection of the echo data K(i) is the same as that of the imaging apparatus 1 in the previous embodiment. Hence the following explains the operation in which echo data K(i) for one subregion R(i) is collected.

0025

As shown in Fig. 9, the movement/imaging simultaneous execution unit 11 controls the cradle 20, to move the object for imaging G at the movement speed Gv. Simultaneously, imaging is started with repetition time TR (11A). If the length in the movement direction of the imageable region 10b of the MRI device 40 is Mw, the length in the movement direction of one subregion R(i) is Gw, and the time to collect data K(i) for one subregion R(i) is Mt, then

$$Gv \leq (Mw-Gw)/Mt$$

From this, the data K(i) can be collected during the time that the object for imaging G is in the imageable region Mw. Fig. 10 illustrates the concept of the maximum condition $Gv=(Mw-Gw)/Mt$. In general, when the data K(i) consists of Q view data, $TR=Mt/Q$.

0026

As shown in Fig. 11, the correction requirement judgment unit 12 first judges whether the movement distance Gv•Mt during collection of data K(i) is sufficiently small (12A). If [the distance] is sufficiently small that motion artifacts can be ignored, as in ultra-fast imaging, corrections are judged to be unnecessary, and only data correction and addition processing are performed (12H) by the phase correction unit 34 and echo data addition unit 35, without starting the continuous movement SAT application unit 14, the continuous movement phase correction unit 15, or the oblique/three-dimensional integrated control unit 16, and control is then returned to the system (EXIT1). When control is returned upon EXIT1, the system collects echo data K(i) for each subregion R(i) while continuously moving the cradle 20. If the movement distance Gv•Mt is not sufficiently small, a judgment is made as to whether the imaging plane is a sagittal image or coronal image parallel to the movement direction (12D). If a sagittal or coronal image, the continuous movement SAT application unit 14 and continuous movement phase correction unit 15 are started (12E). If neither a sagittal nor a coronal image, a judgment is made as to whether the image is an oblique image or three-dimensional image with the imaging plane inclined with respect to the direction of movement (12F). If an oblique or three-dimensional image, the oblique/three-dimensional integrated control unit 16 is started (12G). If neither an oblique nor a three-dimensional image, control is returned to the system (EXIT2) without starting the continuous movement SAT application unit 14, the continuous movement phase correction unit 15, or the oblique/three-dimensional integrated control unit 16. When control is returned upon EXIT2, the system performs error processing.

0027

As shown in Fig. 12, the continuous movement SAT application unit 14 adds spatial saturation pulses as necessary before the normal pulse sequence, and limits the region of occurrence of MR signals according to the position of the object for imaging G for each view. Data for each view is then collected (14A). As shown in Fig. 13, the object for

imaging G moves through the RF excitation region Ms. Hence with respect to the axis coinciding with the movement direction, whether the frequency axis direction or the phase axis direction, MR signals from the same area of the object for imaging G will be shifted in phase for each view. Therefore the continuous movement phase correction unit 15 multiplies the data for each view K'(i)(f,p) by exp{-j2πaΔx/Aw} (where, if the movement direction is the frequency axis direction, a is f, and if the phase axis direction, a is p, and is an integer from (-N/2)+1 to N/2), in which Δx is the shift in position from the gradient center, and Aw is the length of the imageable region in the direction of motion, to obtain the data K(i)(f,p) for the view (15A).

0028

Next, the principle of the above phase correction is explained. As shown in Fig. 14, if the case of movement in the frequency axis direction is considered, the MR signal K(i)(f,p) from the signal source g(x,y) in real space is expressed by eq. (3).

0029

Equation (3)

$$K(i)(f,p)=\int_{-\frac{Pn}{2}}^{\frac{Pn}{2}}\int_{-\frac{N}{2}}^{\frac{N}{2}} g(x,y)\, e^{-j\frac{2\pi}{Fw}fx}\,dx\; e^{-j\frac{2\pi}{Pw}py}\,dy$$

0030

If the x coordinate at the gradient center is x', and the shift in position from the gradient center is Δx, then x=Δx+x', and so eq. (4) is obtained.

0031

Equation (4)

$$K(i)(f,p)=\int_{-\frac{Pn}{2}}^{\frac{Pn}{2}}\int_{-\frac{N}{2}-\Delta x}^{\frac{N}{2}-\Delta x} g(\Delta x+x',y)\, e^{-j\frac{2\pi}{Fw}fx'}\,dx'\, e^{-j\frac{2\pi}{Pw}py}\,dy\;\; e^{-j\frac{2\pi}{Fw}f\Delta x}$$

$$= e^{-j\frac{2\pi}{Fw}f\Delta x}\int_{-\frac{Pn}{2}}^{\frac{Pn}{2}}\int_{-\frac{N}{2}-\Delta x}^{\frac{N}{2}-\Delta x} g(\Delta x+x',y)\, e^{-j\frac{2\pi}{Fw}fx'}\,dx'\, e^{-j\frac{2\pi}{Pw}py}\,dy$$

$$= e^{-j\frac{2\pi}{Fw}f\Delta x}\,K'(i)(f,p)$$

0032

Hence it is sufficient to perform the above phase correction, proportionally to fΔx, on the echo data K'(i)(f,p) measured at a position shifted Δx from the gradient center. Phase correction is similar for the case of movement in the phase axis direction.

0033

Even if phase encoding is not in order of magnitude, correction is performed according to the position shift Δx at each position, so that there is no difficulty.

0034

As shown in Fig. 15, the oblique/three-dimensional integrated control unit 16 determines the tasks of each of the oblique imageable region movement unit 36 and the continuous movement SAT application unit 14, starts each, and collects data K'(i)(f,p) (16A). That is, movement of the imageable region and application of spatial saturation pulses are performed simultaneously, and data K'(i)(f,p) is collected. Next, in the case of oblique imaging, the oblique/three-dimensional integrated control unit 16 divides the movement of the object for imaging G into components in the frequency axis direction and in the phase axis direction, performs phase correction of each through the continuous movement phase correction unit 15, and obtains data K(i)(f,p). In the case of three-dimensional imaging, movement of the object for imaging G is divided into components in one frequency axis direction and in two phase axis directions, phase correction is performed by the continuous movement phase correction unit 15, and data K(i)(f,p) is obtained.

0035

After completion of continuous movement phase correction for each of the above subregions, data correction and addition processing is performed by the phase correction unit 34, which corrects for position shifts of each subregion, and by the echo data addition unit 35, to obtain echo data for the entirety of the imaging range.

0036

As is understood from the above explanation, by means of the imaging apparatus 2 of the above embodiment, imaging can be performed with an MRI device while moving the object for imaging G continuously, even when the imaging range is larger than the imageable region of the MRI device. Moreover, images for the entirety of the imaging range (sagittal image, coronal image, three-dimensional image, oblique image) can be obtained by a single reconstruction operation. And, because echo data is added, the S/N ratio is improved.

0037

When the movement speed Gv is fast, or when the echo time TE is long, it is preferable that "gradient moment nulling" or other movement correction be performed for axes with a component in the movement direction.

0038

Advantageous Result of the Invention

By means of the imaging apparatus using an MRI device of this invention, imaging by the MRI device is possible even when the imaging range is larger than the imageable region of the MRI device, and moreover, an image of the entirety of the imaging range can be obtained through a single reconstruction operation. Because echo data is added, the S/N ratio is improved. And imaging by the MRI device can be performed while continuously moving the object for imaging, so that efficiency can be improved.

Brief Description of the Drawings

Fig. 1 Schematic view of one embodiment of an imaging apparatus using an MRI device of this invention.

Fig. 2 Flowchart of data collection processing by the imaging apparatus of Fig. 1.

Fig. 3 Explanatory diagram of the imaging range and subregions.

Fig. 4 Conceptual diagram of processing by the imaging apparatus of Fig. 1.

Fig. 5 Flow chart of data correction and addition processing by the imaging apparatus of Fig. 1.

Fig. 6 Flowchart showing oblique imageable range movement processing by the imaging apparatus of Fig. 1.

Fig. 7 Explanatory diagram showing movement of the imageable region in oblique imaging.

Fig. 8 Schematic diagram of another embodiment of an imaging apparatus using an MRI device of this invention.

Fig. 9 Flowchart of operation of the movement/imaging simultaneous execution unit.

Fig. 10 Explanatory diagram of the relation between the imageable region, data collection time, and movement speed.

Fig. 11 Flowchart of operation of the correction requirement judgment unit.

Fig. 12 Flowchart of operation during continuous movement of the imaging apparatus of Fig. 8.

Fig. 13 Explanatory diagram of movement of the object for imaging during continuous movement.

Fig. 14 Diagram explaining the principle of phase correction for continuous movement.

Fig. 15 Flowchart of operation of the oblique/three-dimensional integrated control unit.

Fig. 16 Schematic diagram of an example of an imaging apparatus, using an MRI device, of the prior art.

Fig. 17 Explanatory diagram of image seams in the prior art.

Explanation of Symbols

1,2 Imaging apparatus using MRI device

10,40 MRI device

10a,40a Bore

10b,40b Imageable region

11 Movement/imaging simultaneous execution unit

12 Correction requirement judgment unit

14 Continuous movement SA[T] application unit

15 Continuous movement phase correction unit

16 Oblique/three-dimensional integrated control unit

20 Cradle

31 Movement/imaging alternating execution unit

32	SAT application unit
34	Phase correction unit
35	Echo data addition unit
36	Oblique imageable region movement unit
R(i)	Subregion
K(i)	Echo data
G	Object for imaging
Mw	Imageable region
Mt	Time for collection of data for one image's worth of a subregion
Gv	Movement speed
TR	Repetition time
Ms	Slice

Figure 1

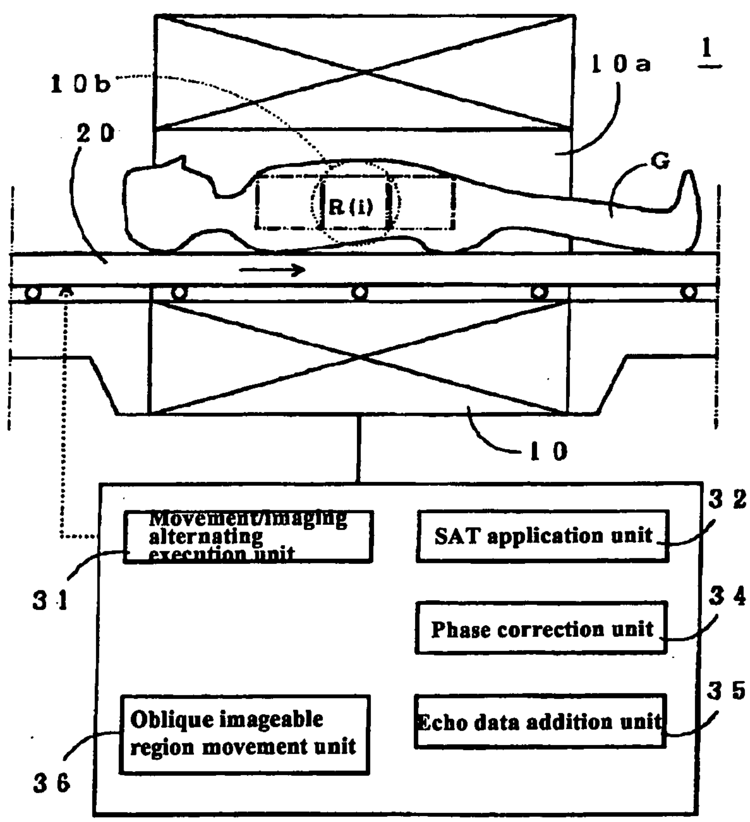


Figure 10

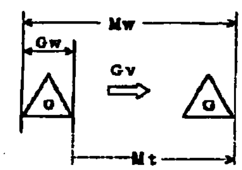
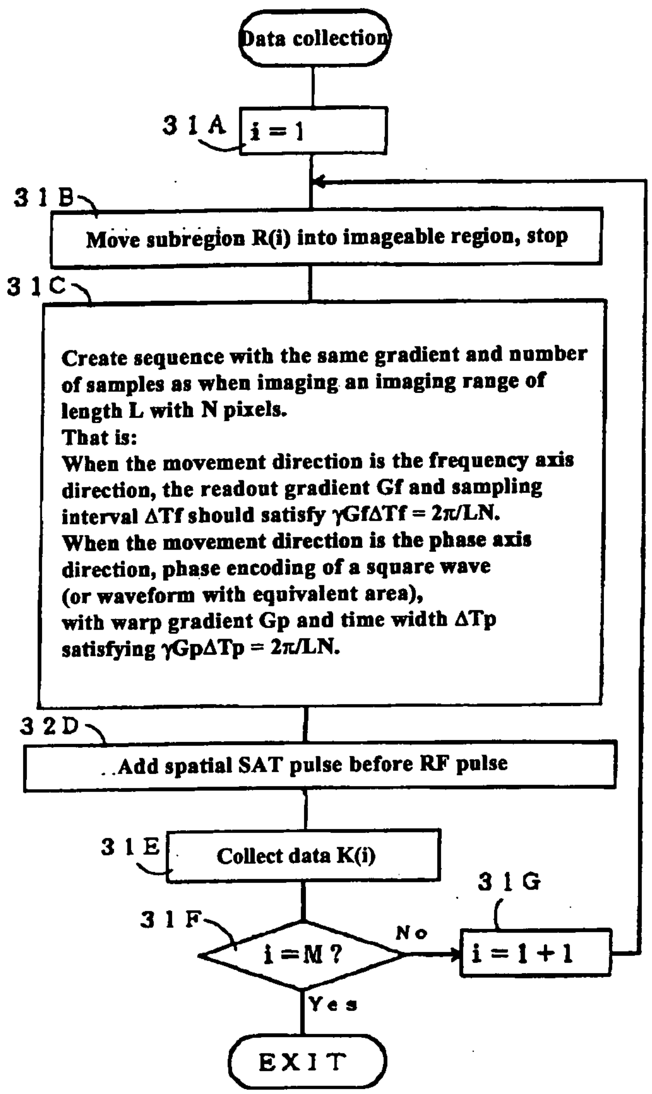


Figure 2



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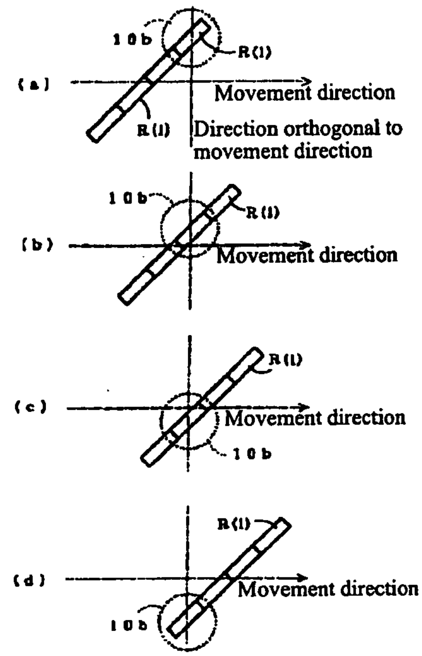


Figure 17

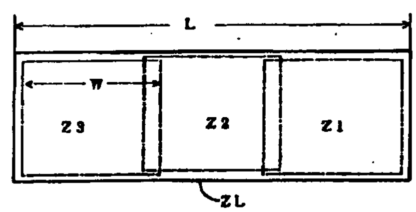


Figure 3

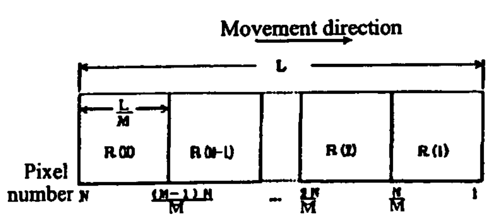


Figure 4

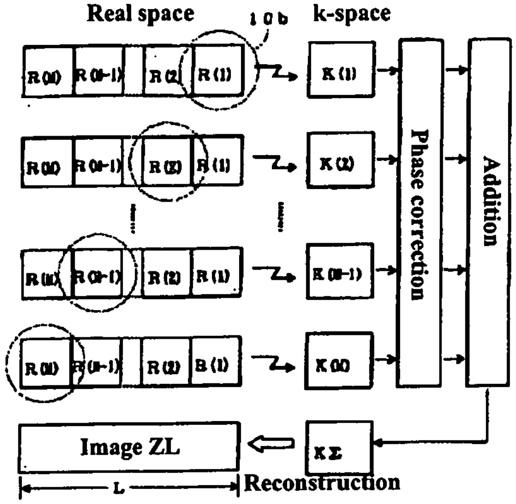


Figure 6

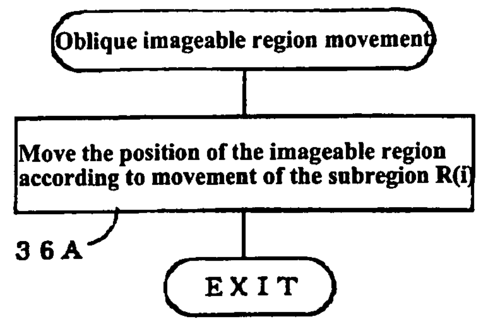


Figure 5

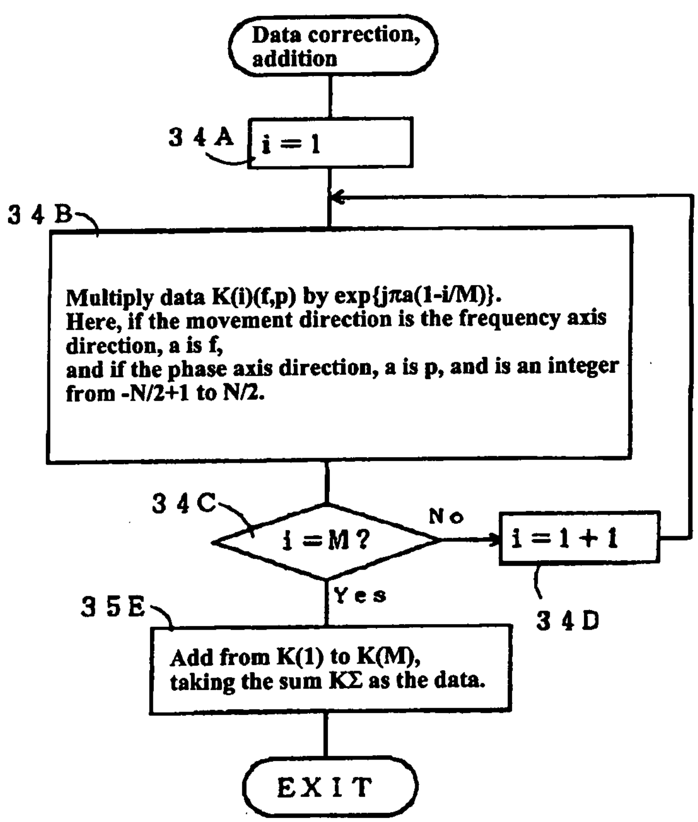
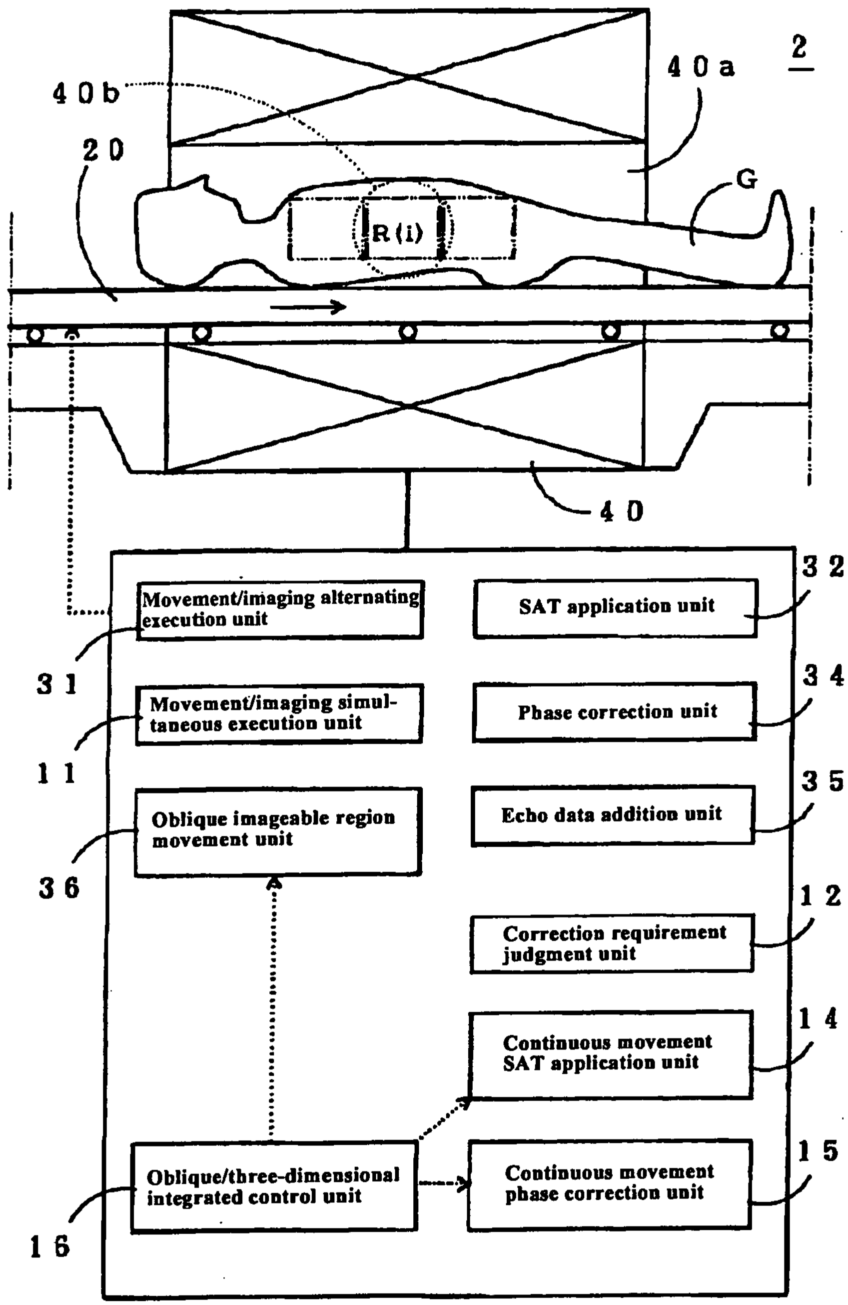


Figure 8



2
4 0 a
4 0 b
2 0
G
R (i)
4 0
Movement/imaging alternating execution unit
3 1
Movement/imaging simultaneous execution unit
1 1
Oblique imageable region movement unit
3 6
SAT application unit
3 2
Phase correction unit
3 4
Echo data addition unit
3 5
Correction requirement judgment unit
1 2
Continuous movement SAT application unit
1 4
Oblique/three-dimensional integrated control unit
1 6
Continuous movement phase correction unit
1 5

Figure 9

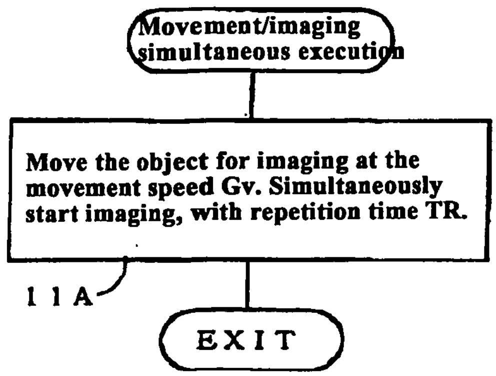


Figure 13

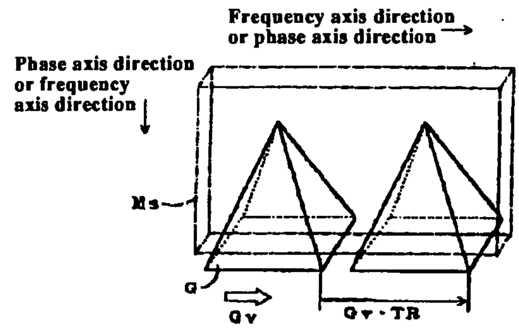


Figure 11

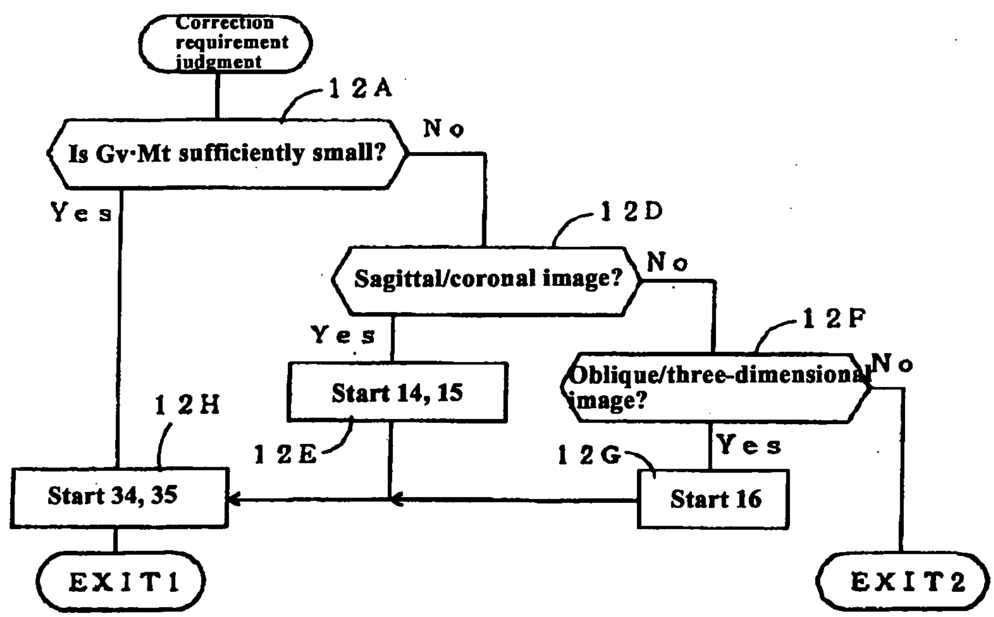


Figure 12

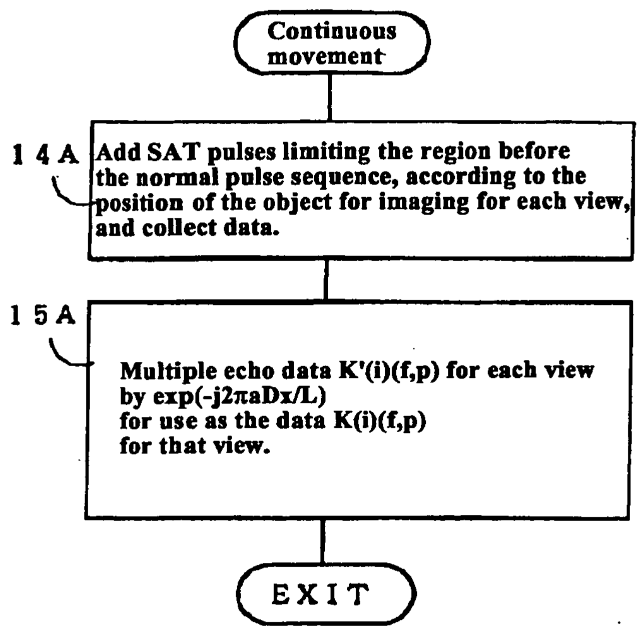


Figure 14

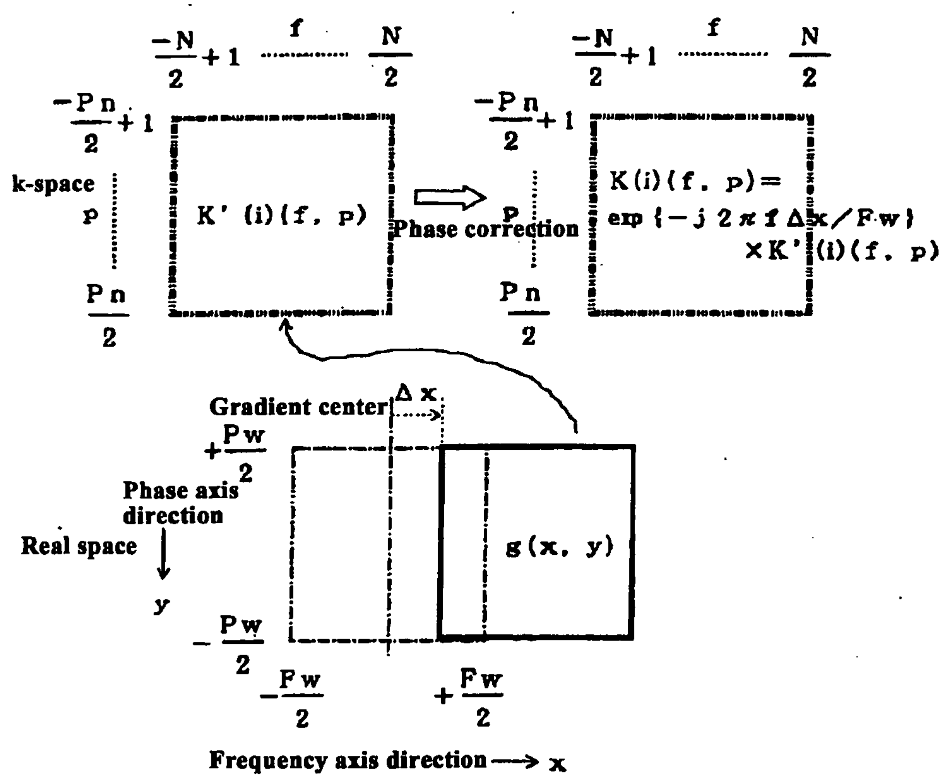


Figure 15

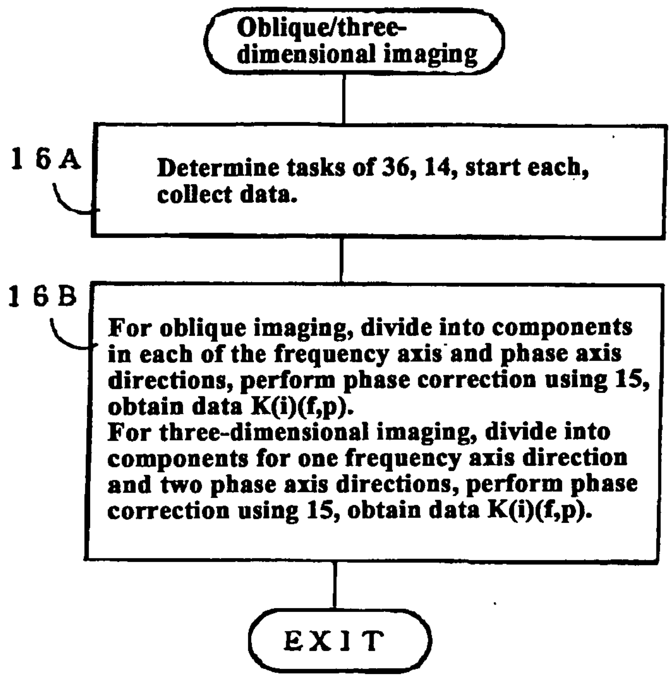


Figure 16